South Buttle Lake (Reservoir) Shoreline Revegetation

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Abstract
Unnatural fluctuation of water levels of Buttle Lake resulting from its use as a reservoir for hydroelectric power production negatively impacts the growth of shoreline vegetation. This impacted area of shoreline known as the drawdown zone is generally sparsely vegetated and represents a highly modified environment that shares characteristics of both riparian and wetland ecosystems. The recognized benefits of intact riparian vegetation on the productivity of fish habitat in lake or reservoir settings support the implementation of revegetation strategies in the drawdown zone. Aesthetic improvements related to the screening of remnant stumps are potential secondary benefits of established woody vegetation. A research site located at the southern end of Buttle Lake in the Strathcona-Westmin Provincial Park was set up to investigate revegetation methods using native woody species. The experimental design included the testing of six seedling species (*Tsuga heterophylla*, *Thuja plicata*, *Alnus rubra*, *Lonicera involucrata*, *Cornus stolonifera*, and *Salix sitchensis*) at three elevations and in two habitat types. The atypical hydrological regime of 2002 prohibited the observation of flood stress, which is predicted to be the major growth-limiting factor of the drawdown zone. A range of species, elevation, and habitat effects were measured in response to drought, herbivory, insect, and general (unattributable) stress factors that were observed. Analysis of seedling survivorship, caliper, and height measurements support the drought and other factors observed in the field. Analysis of soils and climate reveal that the growth of seedlings and revegetation in general may be further limited by changing conditions. Ecologically sustainable revegetation strategies must be developed in accordance with the historic range of variability of disturbance and the ecohydrology of the site. Improved understanding of the ecophysiology of native woody species and plant materials appropriate to the objectives of revegetation are perceived as the primary benefits of the multiyear research program including the initial findings presented here.

Introduction
The abnormal fluctuation of water levels associated with the production of hydroelectric power disrupts the natural establishment of vegetation along the shoreline of the reservoir. This impacted area, known as the drawdown zone, has been the focus of revegetation efforts seeking to rehabilitate the ecological functions of the reservoir setting. The present research is centered on determining the most successful methodology for the enhancement of habitat through the planting of woody riparian species.

Since 1966, Boliden-Westmin (Canada) Ltd. (Boliden) (formerly Westmin Resources Ltd.) has operated a copper and zinc mine in British Columbia, Canada, known as Myra Falls Operation (MFO). Over the past 30 years that MFO has been in operation the mine site environment has experienced a number of ecological disturbances resulting from this industrial activity. The company recognizes the importance of managing its operations in the most environmentally sound manner as part of their responsibility to maintain the integrity of the wilderness environment the mine is situated in.

Myra Creek runs through the mine property and was previously rerouted to accommodate the construction of a tailings disposal facility. The upper reaches of the creek support a small population of cutthroat trout (*Salmo clarkii clarkii*) where the impacts of the mine are minimal. Mining activities predominantly occur adjacent to the middle reach, which also supports limited fish habitat. A multi-year seismic upgrade of the tailings impoundment will result in impacts on the fish habitat in Myra Creek. However, these impacts are mitigated through both in situ and ex situ fish habitat enhancement as part of a fisheries compensation program.

A habitat compensation plan was submitted as the result of the proposed construction by MFO. Golder Associates Ltd. (Golder) was retained to determine habitat compensation alternatives following investigations. One of the compensation measures proposed and accepted by the various regulatory agencies involved was the revegetation of a defined area of the drawdown zone of Buttle Lake (reservoir) (49°31’ N, 125°31’W) to create and enhance fish habitat. The other compensation measure was the construction of a channel that connected a backwater channel with the mainstem of Thelwood Creek.

Boliden has also been encouraged by BC Parks to encompass aesthetic enhancements as an objective within the design of the Buttle Lake experiment and revegetation program. Their primary interest was to improve the appearance of the hummocky western bay through revegetation of its sparsely vegetated exposed surfaces resulting from the reservoir operation (Golder 2001). This requirement has been incorporated into the present study as a secondary objective.

In the past 50 years, Buttle Lake and the surrounding Upper Campbell River watershed have been dramatically altered by human activities. These valued ecosystem components (VECs) are located within Strathcona Provincial Park, British Columbia's first protected area. The park was designed to protect both the recreational and natural values of the diverse wilderness found in central Vancouver Island. However decades of mining, logging, and damming have altered the natural state of this ecosystem, and consequently impacted both human and non-human use. These aspects together with the habitat compensation program provided a unique opportunity for this applied research project, which examines the ecological impacts associated with the control of water levels in the Buttle Lake reservoir for the generation of hydroelectric power.

Golder (2001) suggested that a phased approach to the revegetation be adopted; an adaptive management strategy that incorporated research, field trials, and monitoring was the basis for the study and the multi-year research program being coordinated by Royal Roads University. The original intent of the revegetation program was to integrate the use of both riparian and emergent or aquatic (wetland) species. However, based on the interests of Boliden and the practical scope of the research project, the use of wetland vegetation was excluded.

The experimental design sought to test the impacts of flooding on certain species as the result of the reservoir operations. The research program assessed characteristics of growth and stress of individual seedlings as performance measures of revegetation success. The comparison of calculated levels of exposure to inundation with the growth indicators of the *outplanted* seedlings is the relationship the research project intended to examine. The experiment is designed to support the collection of data and monitoring of the research subjects over multiple years of study. The present study, therefore, describes the preliminary findings of the investigation of revegetation strategies using woody plant materials in the drawdown zone of the reservoir for the purpose of creating and enhancing fish habitat and improving aesthetic values.

The pursuit of ecologically sustainable revegetation methods using woody species requires a thorough understanding of riparian patterns of natural succession. The conclusions support the ongoing research project and are intended to be instructive to other research efforts and revegetation programs being conducted in the drawdown zone. This presentation has been excerpted from the M.Sc. thesis completed by the same author (see MacKillop 2003).

Methods

The research design is based on previous drawdown revegetation experiments where, following a detailed description of the site characteristics, test plots are employed to further examine potential effects of identified seedling growth factors.

Research Plots

The research plots were designed to be 10 m along a contour and 1 m in width to ensure a reasonably uniform elevation to measure the impacts of flooding (Figure 1). Three elevations of 218 m, 219 m, and 220 m were selected for the experiment, which were further divided into the two habitat types identified, *Shoreline* and *Island*. All plots were located on south facing slopes or between 90º and 270º to control for the effect of aspect.

A total of 90 plots were surveyed and distributed within the three elevations and two habitat types. The distribution was intended to reflect the proportional area of the habitat at that certain elevation; however, both the numbers of habitat and elevation plots were disproportionately distributed according to the applied interests of BC Parks.

Seedling Growth Measurement

Each seedling was measured and assessed to establish a baseline immediately following planting. Caliper measurements to the nearest tenth of a millimetre (e.g., 0.1 mm) were taken at the base of the seedling stem(s) as close to the soil surface as possible. Height was measured to the nearest centimetre (cm) from the soil surface to the height of the tallest leaf.

Stress following planting was qualitatively assessed and recorded in the following categories:

1. General occurrence of stress (unattributable) (e.g., level of unexplained damage to seedling parts).
2. Herbivory (e.g., level of stems and leaves browsed; cleanly severed).

Figure 1. Conceptual design of the research plots surveyed along the shoreline contour.

3. Insect damage (level of characteristic leaf or needle consumption patterns).
4. Bleaching or chlorosis (e.g., level of whitening or yellowing of needles or leaves).
5. Dryness (e.g., level of wilting or browning of leaves or needles).

Stress was determined using an arbitrary scale of eight qualifying terms (e.g., no effect, very minor, minor, significant, major, very major, severe, and extreme), which was found to be the easiest way to communicate these attributes between the researcher and the data recorder. Death of a seedling was recorded during the assessment and, subsequently, parameters of growth were not measured.

The complete population of seedlings (885) were assessed and random plots were measured in mid June prior to anticipated flooding. Seedlings were again measured and assessed in mid October 2002, during drawdown, and the approximate end of the growing season.

Statistical Methods

The experimental design encompassed a set of eight dependent variables (survivorship, caliper, height, general stress, herbivory, insect damage, bleaching or chlorosis, and observed dryness) associated with seedling growth. Individual seedlings were divided into sample groups corresponding to three factors. One factor was the six species of seedling that were selected for testing. The other two factors were the two habitat types the seedlings were planted in and the three levels of the elevation factor that were being tested. The factorial statistical design, therefore, can be expressed as 6 X 2 X 3.

A crosstabs procedure was performed for identifying statistically significant relationship(s) (confidence of ≥ 95% or $P \leq 0.05$) between seedling species, elevation, or habitat and survivorship. The uncertainty coefficient value (U) (for nominal data) and the Somers' d-value (for ordinal data) were used as a directional measure to identify the relative strength of significant effects (confidence of 95% or $P \leq 0.05$).

The percent change in caliper values data set was then processed using univariate tests of the General Linear Model® (GLM). Full factorial modelling was used to identify all combinations of effects for each of the factor level combinations of experimental design (i.e., species, habitat, and elevation) during pairwise comparisons. Significance of effects was identified through analysis of the F statistic at a confidence level of 95% or $P \leq 0.05$. The F statistic was based on the linearly independent pairwise comparisons among the estimated marginal means. Strength and direction of effect was estimated using a calculation of estimated marginal means differences ($\pm\mu$). This procedure was repeated for the percent change in height data set.

Results and Discussion

Seedling Growth

The lake was significantly drawn down for maintenance on Strathcona Dam during the initial reconnaissance in early April 2002, resulting in exceedingly low water levels. The persistence of the low water levels was the result of a combination of a delayed freshet and the need to maintain minimum downstream flows.

Despite the conduciveness of the research setting to in-situ experimentation, the atypical hydrological conditions of 2002 significantly diminished the collection of data relevant to the principal design objective of capturing the effect of flooding on the growth of seedlings planted in the drawdown zone. Nevertheless, the results of the data collected are considered relevant to the overall research question and are potentially even more instructive for the management of drawdown revegetation projects. The following sections describe these findings in the context of the atypical environmental conditions.

Lower than normal amounts of precipitation at the research site were also recorded during 2002. A summary of records from the Myra Creek weather station suggests that the climate has been progressively drier for the previous 20-year period (1979 – 2002). The impacts or duration of this micro trend are unknown but warrant further investigation that could help to model the effect of this variability.

A recent report predicts two significant trends for the Upper Campbell watershed based on global climate models: (1) climate will get warmer and wetter, and (2) the watershed hydrology is moving from a snow-driven to a rain-driven system (Loukas et al 2002). Although these predictions describe a fairly remote alteration in the environmental dynamics of the area such further alterations in hydrology or climate of the system could shift habitat characteristics out of the tolerable range of characteristic plant species.

October 2002 Monitoring Data

Lake reservoir water levels remained relatively low (below 218 m) through the 2002 growing season and did not inundate the seedlings planted in the research plots. Moisture stress appeared to have persisted for most of the surviving seedlings from June 2002 as the result of the characteristically warm summer period, southern aspect of the plots, and the prevailing afternoon north winds (personal observation) (Figure 2).

Analysis of the October 2002 survivorship data revealed that the weak effect of elevation within the *Shoreline* habitat to included *T. heterophylla* ($U = 0.098$), *T. plicata* ($U = 0.101$), *A. rubra* ($U = 0.170$), *C. stolonifera* ($U = 0.077$), and *S. sitchensis* ($U = 0.058$). It is anticipated that this effect was a result of competition from the established grass and sedge community for limited resources (i.e., moisture) in the higher elevations of the *Shoreline* habitat. Despite the lack of inundation and the warm weather, these areas flourished with a variety of grass, sedge, and rush species. Further analysis of the survivorship data depicts that habitat type had an effect on all species at the 219 m and 220 m elevations and not on those below with the exception of *L. involucrata* and *C. stolonifera*. Reasons why these species were not similarly impacted are unclear.

The results of the qualitative assessment of dryness and bleaching/chlorosis revealed a strong negative effect (increased stress) of elevation increase on these drought factors for *A. rubra* (*Somers' d* = -0.521) and *T. heterophylla* (*Somers' d* = -0.423), respectively in the *Shoreline* habitat. The seedlings planted in the lowest elevation plots may be the minor exception to this potential drought effect since these plants have had access to the water table and, at times, saturated soils. This is supported by a significant seedling-species dependent effect on observed dryness in the lower elevations of the *Island* (218 m $U = 0.165$, 219 m $U = 0.112$) and *Shoreline* habitats (218 m $U = 0.122$), where certain species such as *S. sitchensis* and *A. rubra* would be expected to be able to access the water table better than others. Similarly, the species effect on survivorship in October 2002 occurred at the lower elevations of both the *Island* (218 m $U = 0.181$) and *Shoreline* (218 m $U = 0.039$, 219 m $U = 0.022$) habitats. Bleaching or chlorosis was primarily observed in the conifer species and revealed an expected species-dependent effect at all elevations and in both habitat types.

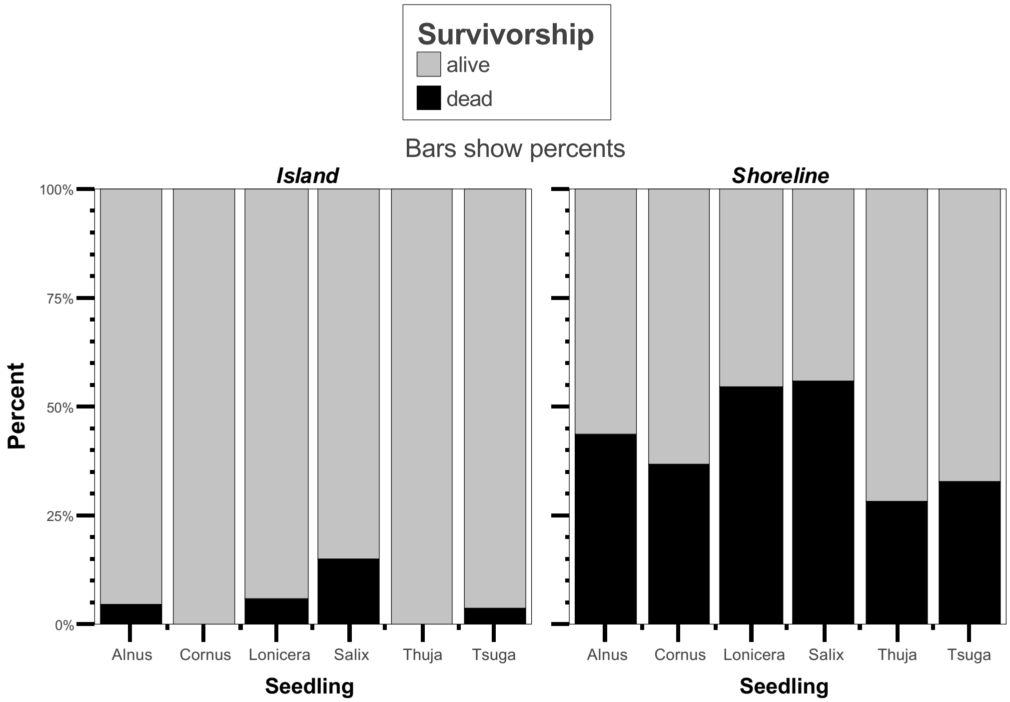

Figure 2. Observed percentage of seedling survivorship by species in October 2002.

Select seedlings in the *Island* habitat area exhibited substantial growth where the soils were more loamy than sandy (personal observation) and therefore suspected to hold more moisture. This may be further supported by the analysis of dryness measures in the two habitats where *T. heterophylla* (219 m $U = 0.198$), *T. plicata* (218 m $U = 0.242$, 219 m $U = 0.166$), *A. rubra* (218 m $U = 0.630$, 219 m $U = 0.103$), and *S. sitchensis* (218 m $U = 0.175$, 219 m $U = 0.162$) demonstrated a significant habitat effect on observed plant dryness at these lower elevations.

Caliper

The General Linear Model® (GLM) subsequently revealed that the average change in caliper values were significantly different for elevations ($F = 18.853$) and revealed estimated marginal means differences ($\pm\mu$) between 218 m, and the upper elevations at 219 m ($\pm\mu = 0.285$) and 220m ($\pm\mu = 0.485$). Visual representations of these trends are shown in Figure 3. Increasing elevation had an overall negative effect on seedling growth in both habitats, as revealed in the marginal means plot. A habitat effect ($F = 19.793$) was found where the estimated marginal means of caliper change decrease moving from *Island* ($\pm\mu = 0.295$) to *Shoreline*. A species effect ($F = 14.523$) on caliper change was further defined by the greatest significant effect between *A. rubra* ($\pm\mu = 0.885$) and *T. heterophylla*. Much of this fits with previously suggested ideas regarding superior access to water resources and less competition from established grass and sedge communities in the lower elevations in the *Island* habitat.

Height

Analysis of the change in height data revealed similar negative effects with elevation increase ($F = 6.512$); in paired comparisons of 218 m to 219 m ($\pm\mu = 0.181$) and 220 m ($\pm\mu = 0.339$). Visual representations of these trends are shown in Figure 4. Significant habitat effects were not found; however, species effects were found to be significant for change in height in paired comparisons ($F = 12.668$). *Cornus stolonifera* had the smallest increase in height, on average. *S. sitchensis* demonstrated the greatest mean changes in height of all species, topping *T. plicata* ($\pm\mu = 0.495$), *T. heterophylla* ($\pm\mu = 0.328$), and *A. rubra* ($\pm\mu = 0.293$). Other significant mean differences between species included *L. involucrata* that, on average, grew more in height than *T. plicata* ($\pm\mu = 0.485$), *T. heterophylla* ($\pm\mu = 0.318$), and *C. stolonifera* ($\pm\mu = 0.981$). The remaining two significant differences observed were relative to *C. stolonifera* and based on the estimated marginal means of *A. rubra* ($\pm\mu = 0.699$) and *T. heterophylla* ($\pm\mu = 0.663$).

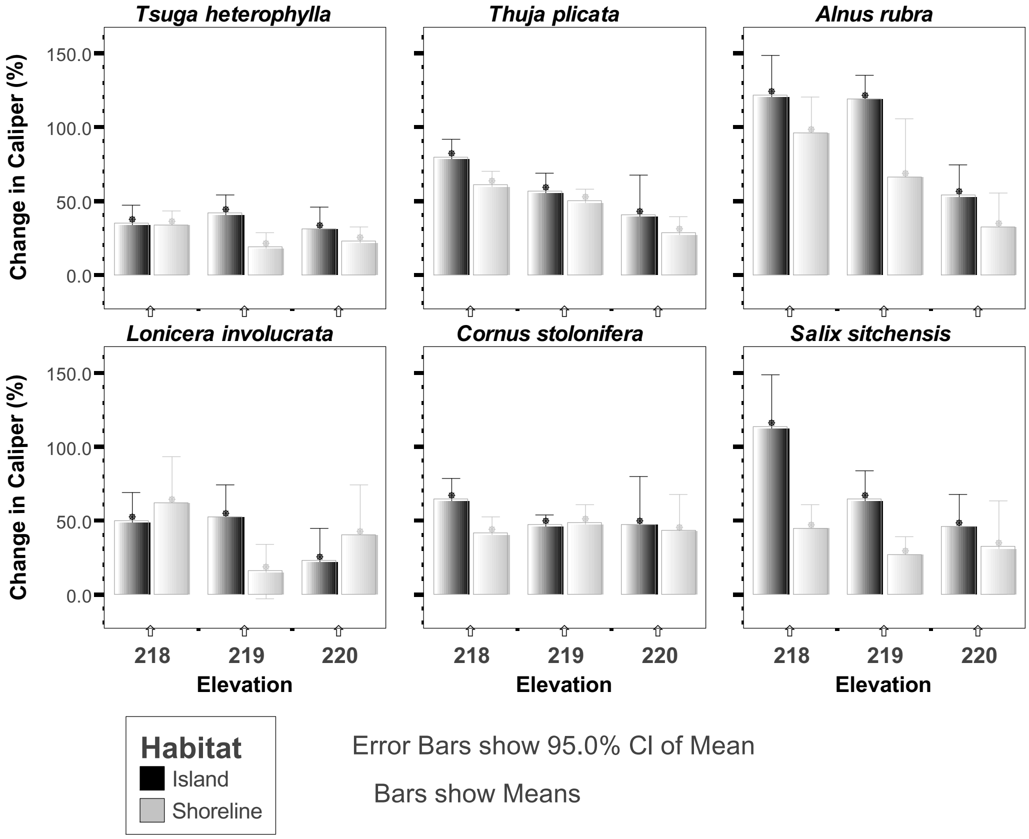

Figure 3. Bar charts depicting the change in caliper (%) measured for each species at three elevations and two habitats.

Species including *S. sitchensis* and *L. involucrata* were, on average, the shortest seedlings outplanted. These seedlings were different in form, as mentioned above, which may account for the significant differences between these species and the others. *Salix* spp., in particular, are known for rapid growth, especially in the elongation of thin stems and branches. Greater growth differences for S. *sitchensis* at the lower elevations is likely explained by its ability to access available water resources more rapidly than other species (Pojar and MacKinnon 1994).

In the case of *L. involucrata*, its unique ability to develop many branches during growth (personal observation) could distort the values of height change observed. Attempting to efficiently measure the major proportion of the greatly twisted branch height(s) and the resulting frequency of measurement and calculation increases the chance for error (personal observation). This may also explain why this species had the greatest number and magnitude of disproportionate height to caliper ratios.

C. stolonifera did not perform well relative to the other species in average height change, which could be the consequence of herbivory damage discussed below, or, as with *L. involucrata*, may be a false effect related to numerous measurements and calculations from multiple-stemmed seedlings.

Seedling Damage

Herbivory was recorded based on observations of cleanly broken stems and branches near the tops of the seedling which were suspected to be the result of Roosevelt elk (*Cervus elaphus roosevelti*) and Columbian black tailed deer (*Odocoileus hemionus columbianus*) browse. Although black bears (*Ursus americanus vancouveri*) were seen in the immediate area on a daily basis prior to planting, no other forms of herbivory were observed.

Analysis of the herbivory data and field observation confirm that there was a weak seedling species-dependent effect on the level of herbivory observed occurring in nearly all elevations of both habitats (U range = 0.027 to 0.096); the exception being the 220 m elevation of the *Island* habitat. This weak effect may highlight an inability to distinguish levels of herbivory in the conifer species as readily as the angiosperm species (Figure 5).

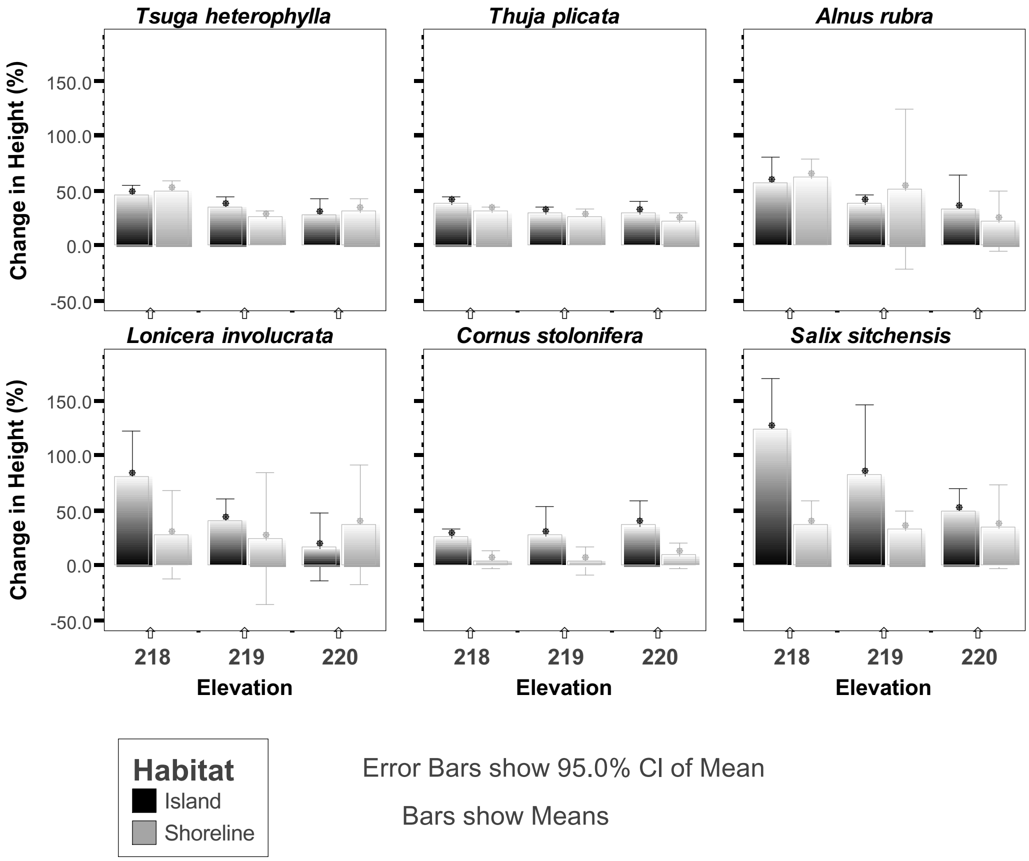

Figure 4. Bar charts depicting the changes in height (%) measured for each species at three elevations and two habitats

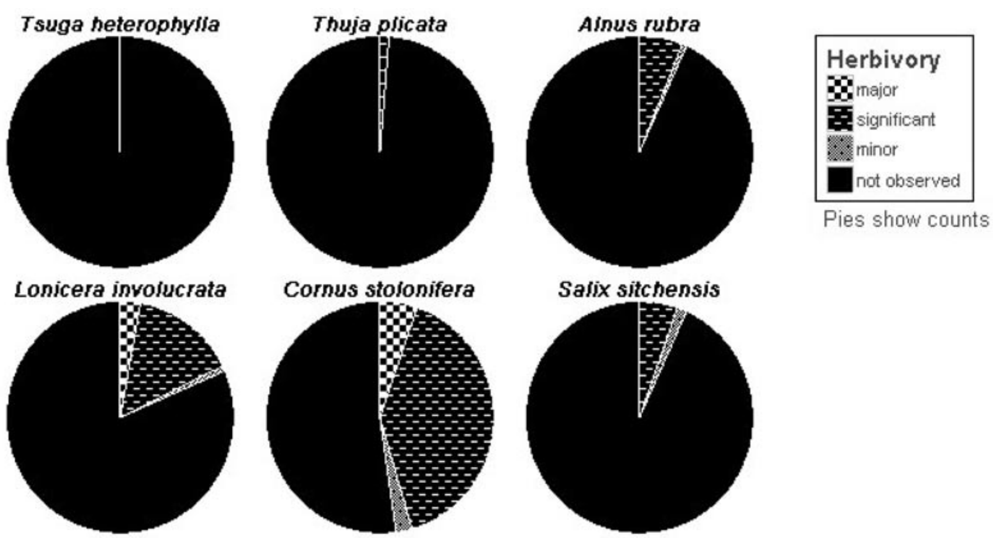

Figure 5. Pie charts depicting herbivory observed for each species during 2002 season.

The stress data that measured relative insect damage was also fairly inconclusive and is therefore not reported here. Leaf or stem damage that could not be easily attributed to a defined cause or factor was recorded using the same qualitative scale as used for other stressors. These results are difficult to interpret since the nature of the impacts is not known and its effect was uniformly more significant in the *Island* habitat.

Recommendations

Plant Materials

The design of the experiment was primarily aimed at gaining insight on what planting methodologies using woody species are most suitable for the southern portions of Buttle Lake drawdown. Two major elements of that insight were anticipated to be an understanding of which species of seedling planted performed best, and at what elevation range. Without the flooding effects of the typical high water summers imposed by the reservoir management, this understanding could not be obtained from the collected data. The results of this study, nevertheless, support the conclusion that, in the absence of flooding effects, the growth of the majority of seedlings was limited by access to water resources during the growing season. Other stress factors were also identified and were demonstrated to have contributed via significant, albeit weak effects on seedling growth and survival.

Observations of the ecological dynamics provided useful insight into the nature of the drawdown zone at various locations in Buttle Lake. Many of these locations are sparsely vegetated, but there is a variety of species found both at the boundary and within this zone. The majority of these species are described as pioneer species that are associated with disturbed sites and exhibit the rapid growth and tolerance of environmental extremes characteristic of this general grouping.

Salix

There are few woody species in comparison to the herbaceous varieties that have established in the drawdown zone of Buttle Lake. The most prevalent of these is *Salix sitchensis*, or Sitka willow, which was identified in a variety of forms and microhabitats discontinuously throughout the research site and the eastern shoreline of the lake. This plant has been found growing on stumps to rubble beaches. Its tenacity may be derived from both its ability to withstand the effects of periodic flooding, as well as more drought-like conditions. The success of plant growth in response to flooding is not confined to its ability to adapt to hypoxic soil conditions (associated with flooding), but rather it must also be equipped to respond to aerobic conditions once restored (Crawford 1996).

Alnus

Another species that is commonly found in the drawdown habitat is *Alnus rubra* or red alder. This species most certainly demonstrates the rapid growth characteristic of pioneer plants; it has a well-documented tolerance for flooding although generally not considered as tolerant as members of the *Salix* genus. Perhaps most impressive is its ability to propagate rapidly through both seed and vegetatively as an early successional species (Peterson, Ahrens, and Peterson 1996). The low water levels and exposed shoreline demonstrated this clearly, where a multitude of seedlings quickly regenerated wherever parent stock of alder was nearby.

Mature *Alnus crispa* ssp. *sinuata* or Sitka alder were identified at the borders of other drawdown sites and was planted extensively as part of the revegetation program discussed here. The nitrogen fixing abilities of *Alnus* species provide a critical ecological service that potentially mitigates the soil fertility issues identified in the soils analysis (Haeussler et al 1990). It will be most interesting to observe how the natural colonization of *A. rubra* seedlings will respond to more typical water levels and the associated impacts of flooding, once this resumes.

Cornus

Cornus stolonifera or red osier dogwood was identified in the upper elevations (220 m – 223 m) of the drawdown zone and has been discussed as a suitable species to evaluate for revegetation by other researchers (Carr et al 2000). The findings presented here along with a more recent site visit reveals that its preference as forage by ungulates in the area may warrant limiting its use in future revegetation work.

Lonicera

Lonicera involucrata or black twinberry is not a species that is customarily used for revegetation work in this region, which may be the result of its negative response to handling, unique form, or potentially poisonous berries. However, the use of *L. involucrata*, which is not currently on the recommended species list may assist in meeting the planting criteria set forth by the provincial government that suggests the use of a minimum of 50% fruit-bearing species. (BC MELP 1998a).

Thuja and Tsuga

Another criteria recommended for riparian revegetation in British Columbia is the use of at least 10% but not more than 25% of the total planting stock as conifer species. *Pseudotsuga menziesii* or Douglas-fir was observed throughout the exposed areas of the drawdown during the periods of low water levels as newly regenerating seedlings. Although its preference for drier site conditions was suitable for the growing season of 2002, its low tolerance for flooding is expected to slow or eliminate its continued establishment once a more typical regime returns.

T. heterophylla is a dominant species in many of the ecosystems adjacent to the site and has demonstrated its ability to establish in the upper elevations of the drawdown zone. It is not considered to be tolerant of long periods of saturated soil conditions particularly during growing temperatures (Walters et al 1980). Therefore, it is anticipated that its success in the fluctuating hydrology of the Buttle Lake shoreline will be limited at best despite its performance during atypical conditions of 2002. It was primarily planted as a reference species that would perhaps illustrate the flooding tolerance of the other test species through comparison.

Alternatively, *T. plicata* is expected to have success in upper elevations of the drawdown zone due to its documented ability to withstand periodic flooding. The greater challenge for *T. plicata* seedlings in getting established may be the impacts of herbivory, which were observed at the site. Similar to the *C. stolonifera*, *T. plicata* is a preferred forage material for both Roosevelt elk and Columbian black tailed deer. The young shoots are particularly favoured by these ungulates, and the seedling top or leader, therefore, must be protected to ensure continued growth. Several protective devices have been designed to address this problem and many are considered to be successful based on extensive trials and experience (Conner, Inabinette, and Brantley 2000). The cost of obtaining, installing, and maintaining these shelters are the major deterrents to their use; however, in this setting, the relatively easy site access for maintenance activities and consideration of the provincial recommendations may justify the protection of the *T. plicata* seedlings.

Other Species

A number of other native tree and shrub seedling species have been planted in the upper elevations of the drawdown zone as part of the revegetation program, both in the spring and fall of 2002. Many of these seedlings planted in the spring 2002 appear to have been similarly impacted by a possible the lack of adequate moisture. This indicates that the selected research plots are representative indicators of the larger plantation and environmental conditions at the site. These impacts were surely enhanced by the planting of species that are generally adapted to moist, flood-prone habitats.

One area of interest will be any information that reveals species or planting methods that might improve performance in the *Shoreline* habitat where established grass and sedge communities are a source of potential competition. There is a possibility that these flood tolerant herbaceous species may help to facilitate the growth of woody plant species that can access the more-aerated *rhizosphere* associated with these wetland plants, during periods of inundation (Cronk and Fennessy 2001).

The use of a diverse collection of species and plant materials addresses one aspect of an ecological sustainability approach that is supported by the literature (Manci 1989). Although the heightened variability in environmental conditions observed at this site is recognized as a limiting factor for many species and seedling growth in general, the diversity of species planted should better enable an evaluation of which species are best suited to establishment in this dynamic ecosystem.

Another area that is relevant to the development of the revegetation strategy is the planting of herbaceous species. Once the woody materials can establish and begin to trap sediment, the herbaceous species can then be established through a variety of methods such as seeding, transplant and other bioengineered solutions (Carr, unpublished proposal 2003). Alternatively, a natural re-establishment of herbaceous species might be facilitated by a young, growing tree canopy, which emphasizes the importance of monitoring natural succession in future studies. This component of the revegetation plan has been thoroughly reviewed in an unpublished report by this author submitted for completion of a Diploma in Restoration of Natural Systems at the University of Victoria in spring 2003.

Indicators of Seedling Performance

A proposed monitoring schedule that allows for the timely collection of information, and periodic reporting can inevitably drive an adaptive management approach. This aspect has been identified as fundamental by those with insight gained from many years of reservoir revegetation experience (Allen and Klimas 1986; Carr et al 2000). This schedule is framed within the ongoing support of the applied research component, emphasizing that continual support of the annual monitoring pattern, wherever possible, is needed.

The data from caliper and height measurement is proposed as the optimal indicators of seedling growth in response to the research site conditions. The intended use of this quantitative set of data is ideally to be plotted against the quantified inundation pattern (timing, depth, and duration) of the Buttle Lake drawdown zone according to the elevation of the planted seedling. In the absence of the inundation effect, the data sets continue to serve the role of measuring the growth response of the seedling in a more qualitative fashion.

Performance measures should be developed to incorporate existing measurements and provide information on the ability of the site revegetation management activities to accomplish the stated objectives. These performance measures should be developed in coordination with research and other activities, or be adapted from existing monitoring programs that have similar ecological goals such as the improvement of Roosevelt elk forage in the Thelwood Valley. These performance measures must be regularly reviewed for their efficacy concurrently with research findings.

Fish Habitat Creation or Enhancement

The effects of the revegetation efforts at south Buttle Lake on fish habitat have not been measured as part of the experimental design. A vast amount of research has been conducted on the aquatic life of Buttle Lake demonstrating that improvements in water quality have had a recognizable effect on the overall health of the system (St-Cyr et al 1997). The creation or enhancement of fish habitat is considered an important element to support potential fish population increases.

Mature woody vegetation at or near water’s edge is a similar improvement to cover and structural complexity. Revegetation should also result in improvements in the microclimate of the littoral zone, nutrients contributed to the aquatic and littoral zone, and habitats available for terrestrial and aquatic insects and other invertebrates (Golder 2001). These effects could be measured in terms of fish habitat as the observed change in density or number of both individuals and species, as part on the current monitoring program of the provincial government. Baseline measurements of these parameters need to be developed that could be potentially established from the existing database and data collected in the near future.

Specific measures that quantify parameter changes should also be developed (e.g., nutrient analysis, water temperature, surveys of insect or invertebrate populations). However, these parameters, as reported by Compass Resources et al (2000) may not be as revealing as direct measurements of fish activities, habitats, or populations (e.g., density and number).

Aesthetic Improvements

The aesthetic concern associated with the drawdown zone has been clearly defined; the combination of sparse vegetation, debris from flooding and remnant stumps has degraded the visual quality (Strathcona Provincial Park Advisory Committee 1988; Carr et al 2000). Based on the understanding of the park visitor through previous surveys conducted by BC Parks it can be expected that an improvement in the scenic value of south Buttle Lake is desired (BC MELP 1993). Aesthetics improvements of the *viewshed* of the Thelwood Creek Bridge viewing area should address the visual impact of the drawdown zone, which is in the foreground of the views north. The revegetation of the drawdown zone is intended to diminish the *visual salience* of the remnant stumps as the growth of woody vegetation begins to screen these elements from view. The *Island* habitat of the western bay is the most visually impacted by the presence of stumps at visible elevations. The effect of the screening is anticipated to develop the *intactness* and *unity* of the overall visual experience while not degrading the vividness of the Buttle Lake valley in the background.

The use of pictures to show temporal changes is becoming more widely applied as a tool for environmental management. Documenting landscape changes over seasonal, annual, and longer time periods enable a wide audience an opportunity to recognize the successional patterns visible in nature.

Three photopoint monitoring stations have been established at the Buttle Lake revegetation research site as an important component of the overall monitoring program. The intention is to catalogue both the natural successional and restorative changes that are occurring, and describe any improvements to the aesthetics of the site.

Ecological Sustainability

Ecosystems that experience disturbance outside of the historical range of variability are considered highly modified. For highly modified ecosystems like the drawdown zone of Buttle Lake, a set of performance criteria should be correspondingly modified to fit both the environmental goals of the immediate area and the surrounding landscape. The Wildlife Society (2002) suggests that these modified areas can be managed as a matrix that are within or envelope more natural ecosystems. This matrix can beneficially function by providing habitat for native species, passage between natural areas (corridors), and ecosystem components that might facilitate recovery from disturbances (The Wildlife Society 2002). Performance measures should therefore assess whether the current environmental management practices support similarly defined goals and objectives under the modified disturbance regime. Thus, the sustainability of these practices can be assessed according to the ability to achieve these objectives without requiring continuous input for the duration of ecosystem modification.

Conclusion

The findings of this study were supportive of field observations, which described characteristics of drawdown vegetation including outplanted seedlings responding to moisture stress. This moisture stress was the result of low reservoir levels according to an atypical regime in 2002. Stress was significantly higher in the *Shoreline* versus the *Island* habitat type due to competition with existing vegetation communities. Increases in growth and decrease in stress were associated with the lower elevations in the design and contrasted what would be expected under the more typical flooded hydrological regime of the research setting.

Species effects were diverse and complex, allowing for only preliminary conclusions about the performance of species. Field observations of *S. sitchensis* growing in numerous locations at lower elevations of the drawdown zone suggest that it should perform better than most in this setting. The literature strongly supports the use of dormant cuttings for *Salix* spp. and a number of guidelines can be found in the review of those relevant findings.

Species such as *C. stolonifera* and *T. plicata* have characteristics that are important to recommendations of the provincial government and appear to be ecologically suited to these site conditions. However, the impacts of forage by elk and deer were demonstrated to have an effect on their performance and it is recommended that the use of browse protectors be reviewed.

All seedlings planted to date will be monitored according to a schedule recommended in this study (MacKillop 2003). These findings should serve to augment the future experimental results and conclusions. Revegetation strategies as part of the overall program should be implemented as early as possible to address habitat compensation timelines and an adaptive management approach. Monitoring of those sites that are not revegetated is an important reference (baseline) to evaluate the performance of unique strategies.

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